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APPLICABILITY OF DRAG REDUCING AGENTS IN DOMESTIC HEATING SYSTEMS

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INTRODUCTION

A large part of the auxiliary energy for cooling and heating systems in buildings is needed for pumps that distribute the heat transfer medium in the thermal distribution network. In the BioNet-project at Hermann-Rietschel-Institut in Berlin, causes for energy loss in the networks are investigated and methods inspired by the bionic science are developed and evaluated to optimize the hydraulic components of networks, improve their efficiency and save energy. The considered methods are categorized into geometrical optimization of fittings, resistance-reducing surfaces of pipes and the addition of drag reducing agents (DRAs) into the heat transfer medium that is commonly water [3].

The optimization of fittings were performed and evaluated for a bend and a T-split. The outcome were the bionic bend [6] and several advanced T-split geometries [5]. The application of these fittings result in a reduction of additional pressure losses up to 35 %. The implementation is straightforward because it is possible to replace a conventional fitting by an optimized one directly.

Own experimental studies with different micro-structured surfaces indicated that the use of resistance-reducing surfaces within the pipe is less promising. The general potential to reduce the pressure losses is existing but the small hydraulic diameters of domestic heating nets poses a strong challenge.

However, the capability in saving energy by using DRAs is very promising especially the use of surfactants. Therefore in literature are several publications available investigating rheological and hydraulic characteristics of drag reduced fluid flow [7]. But there are also drawbacks and problems that lead to an increased technical demand in newly constructed systems or an ineffectiveness in consisting systems [2]. For this reason the application of DRAs is not established and has seldom been used in heating nets. Nevertheless, there are examples for applications of DRAs especially in district heating nets that were already successfully tested [1].

District heating nets are characterized by large hydraulic diameters, long straight pipes with few deflections, high capacities and fully turbulent flow conditions. To make a prediction about the efficiency of a DRA a straight test section with length L is often used and the pressure drop Δp for given volume flow rates Q is measured. Thereby the Reynolds number Re_s and friction factor λ can be determined to characterise the fluid flow non dimensional with D_h as hydraulic diameter of the pipe, u as mean velocity in the pipe and ν_s and ρ_s as kinematic viscosity and density of water hereafter referred to as solvent s:

$$Re_\mathrm{s} = \frac{D_h \cdot u}{\nu_\mathrm{s}} \qquad \lambda = \frac{2 \cdot \Delta p}{\rho_\mathrm{s} \cdot u^2} \cdot \frac{D_h}{L} \tag{1}$$

Comparing the results with reference data or a correlation for the friction coefficient λ_ref of water through a smooth pipe e.g. the Blasius correlation, the drag reduction DR can be quantified:

$$DR = \left(1 - \frac{\lambda}{\lambda_\mathrm{ref}}\right) \cdot 100\,\% \tag{2}$$

The situation is different in case of domestic heating systems. They have a shorter total length with smaller hydraulic diameters and a large share of flow deflections, separation and junctures. The flow conditions are rather transient and unsteady. This implies that for the experimental characterization a measurement of pressure drop in a straight section is insufficient and predictions for domestic heating networks will be mostly overestimated and not applicable.

Therefore a special test rig was built to investigate the applicability of DRAs especially in domestic heating systems, detect problems inside the technical implementation and describe the difference between ideal characterization and application.

EXPERIMENTAL METHOD

A schematic illustration of the test rig is shown in figure 1 and will be briefly introduced in the following. More and detailed information about structure and properties were given by Tawackolian et al. [6] and Tawackolian [4].

The test rig consists of three different test sections. First, the test rig contains a pipe with several pressure connectors to measure the hydraulic resistance of a developed flow in a straight measuring section. Furthermore, the test rig has two spiral water circuits. Each circuit has a total length of $L = 5.555$ m and includes ten bends that deflect flow and cause disturbances as occur in realistic hydraulic networks [4]. The difference between both of them is that one circuit is equipped with conventional bends and the other one with bionic bends.

Except the laser sintered bends of both circuits all used tubes and fittings of the test rig consist of copper and have an inner diameter $D_h = 16$ mm. A centrifugal pump is used to provide a continuous flow rate. The flow rate is measured by an electromagnetic flow meter (EFM) and is adjusted by a control valve manually. In the whole measuring section pressure drop (differential pressure transducer) and temperature (Pt100 resistance thermometer) are measured. A dosing pump with an injector is used to adjust the required surfactant concentration in the flow.

As DRA Arquad 16-29 purchased by JuliusHoesch company were used. Arquad 16-29 comprise 29 % cationic surfactant cetyltrimethylammonium chloride (CTAC) and 71 % pure water. In addition sodium salicylate (NaSal) was used as counterion. During the measurements the molar counterion-to-surfactant ratio $\tilde{R}$ was kept constant ($\tilde{R} = 1.5$).

Three different concentrations of CTAC (75, 125 and 250 ppm; related to the total fluid volume of the test rig) were tested at a nearly constant temperature in the straight pipe to assess the general behaviour of DRA in fluid flow. Afterwards, the solutions were tested in the conventional and in the bionic circuit. As reference, all test sections were tested with pure tap water (0 ppm).

RESULTS

Figure 2 shows that the drag reduction depends strongly on Re_s number and surfactant concentration. It can be seen that drag reduction appears only in a certain range of the Re_s number. This effect is based on the self-healing properties of surfactants forming a shear induced structure (SIS) out of cylindrical micelles and is well documented in literature [1, 7]. This drag-reduced range is shifted by changing the concentration. A high surfactant concentration provides a stable drag reduction for high Re_s numbers. Simultaneously the drag reduction is less intense for low Re_s numbers. This means that for application the surfactant concentration has to be well defined.

Comparing drag reduction of the straight pipe and the conventional circuit it can be stated that the drag reduction in the water circuit is decreased for all tested concentrations. One cause for the decreased drag reduction can be an increased pressure drop through deflection in the bends described by the pressure loss coefficient ζ_u. Therefore an averaged ζ_u-value of a bend in the water circle was calculated according to the approach by Tawackolian et al. [6].

Figure 3 shows that the averaged ζ_u-value of drag reduced flow is greater than ζ_u-value of water flow for low Re_s numbers. If $Re_s > 20\,000$ this effect vanishes and the ζ_u-value don't depend on surfactant concentration any more. By using the bionic bend the ζ_u-value can be decreased for all tested concentrations.

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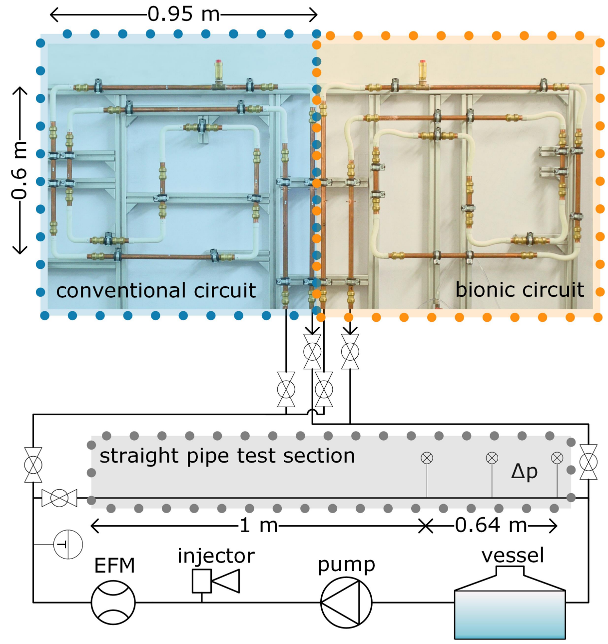

Figure 1: Schematic illustration of the test rig.

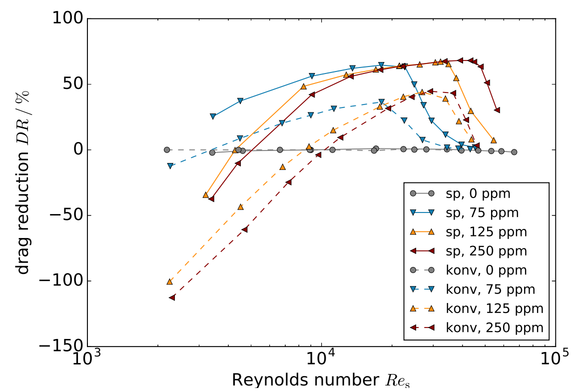

Figure 2: Drag reduction measured in the straight pipe *sp* and the conventional circuit *konv* in dependence on Reynolds number.

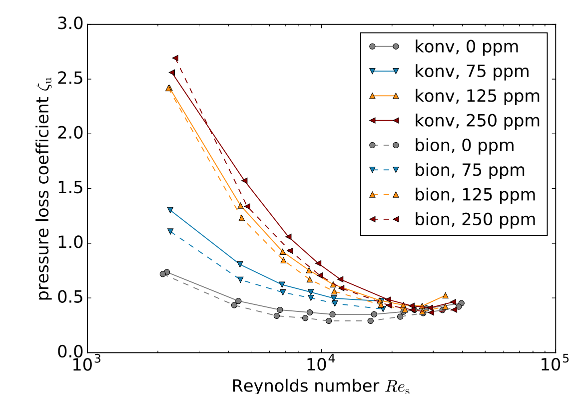

Figure 3: Averaged pressure loss coefficient of a bend in the conventional circuit *konv* and a bend in the bionic circuit *bion*.